Formaldehyde in Indoor Air of New Appartments in Drama, Greece

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Abstract

This work aimed at evaluating the indoor concentrations of formaldehyde in twenty five new apartments in the city of Drama, Northern Greece. By means of a formaldehyde meter, two series of measurements were made in September 2009 and September 2010. Early morning measurements were made in the living rooms, bedrooms, kitchen rooms and child rooms. Initial measurements showed that average concentrations of formaldehyde exceeded by far the limit of 0.1 ppm set in most of the European countries for formaldehyde concentration in residential environments. After a 30-minute natural ventilation in the apartments, formaldehyde concentrations remained at the levels higher than 1.0 ppm only in three apartments. In the following months (September 2009 to September 2010), a systematic ventilation by opening windows took place not only in the morning but also in the late afternoon. In September 2010, measurements were performed in the same apartments indicating that all apartments investigated had formaldehyde concentrations much lower than 1.0 ppm and obviously the indoor air environment was much cleaner.

Keywords

Formaldehyde; Emission; Air

Introduction

Indoor air quality is an important issue because people spend most of their time in indoor environments where there may be more pollutants and higher concentrations than outdoors (Godish 1989a, US EPA 1991, Li *et al.* 2001). In particular, the levels of volatile organic compounds (VOCs) found indoors are generally reported to be greater than outdoors (Ilgen *et al.* 2001, Pośniak *et al.* 2005, Khoder 2006). Consequently, indoor air quality is liable to influence human health compared to outdoor air quality. Poor indoor air quality has been linked to a number of symptoms, which the World Health Organisation has defined together as *Sick Building Syndrome* (US EPA 1991, Kostiainen 1995). It is well known that the most common indoor pollutant is formaldehyde (Dally *et al.* 1981, Breysse 1985, Brown *et al.* 1996, Mantanis and Markessini 1998, Hodgson *et al.* 2000). Formaldehyde is classified to be toxic and irritating to the respiratory tract, eyes and skin (National Research Council 1981) and carcinogenic to humans at high concentrations (The Japan Society for Occupational Health 2002, IARC 2004).

The sources and levels of the VOCs in indoor air vary depending on the type of building. Major sources are construction materials, furnishings, cosmetics and textiles, paints, carpets, architectural finishes, insulation, fabrics and paper, varnishes and solvents, adhesives, cleaning compounds as well as combustion by-products (Samfield 1992, Kelly *et al.* 1999, Guo *et al.* 2000, Guo and Murray 2001, Kwok *et al.* 2003). Combustion, particularly tobacco smoking, and photocopying or laser printing on paper, strongly influences the indoor concentrations of VOCs (Etkin 1996, Baek and Jenkins 2001).

Formaldehyde concentration in new houses has been reported to be at very high levels (Dally *et al.* 1981, Godish 1989b, Kostiainen 1995, Brown 2000, Khoder *et al.* 2000, Mantanis 2007). Evidently, kitchen closets and cabinets in new apartments alone have the potential to cause residential formaldehyde to rise higher than 0.1 ppm (Godish 1989b). Zhao *et al.* (2004) also reported that, in freshly decorated houses, formaldehyde concentrations were up to 0.41 ppm. In Australia, measurements in suburban Melbourne residences more than a year after construction identify twenty seven airborne toxics including the carcinogens benzene, formaldehyde and styrene. The study concluded that occupants of new homes can be exposed to up to 20 times the maximum allowable

limits of indoor air toxics (Brown 2000). The measurements indicated that long-term indoor air pollution is likely from new building materials emitting formaldehyde such as manufactured wood-based panels used principally in flooring, furniture and cabinets. Menteşe and Güllü (2006) reported that formaldehyde concentration inside homes, although averaged at around 0.06 ppm, rise in some residences as high as 0.71 ppm depending upon indoor and outdoor temperature, room age of house and density of the plywood furniture. Khoder *et al.* (2000) found that in new flats, the maximum formaldehyde concentration was up to 0.35 ppm in residential homes in Cairo and noted that air temperature, relative humidity and age of the flat were the main factors affecting the emission and concentration of formaldehyde. Minami *et al.* (2002) reported that in a new private house, formaldehyde concentrations ranged in between 0.07 and 0.23 ppm during the first months, while natural ventilation by opening windows was effective to lower the formaldehyde concentration in the indoor air.

Previous studies on indoor air quality in Greece have focused on volatile organic compounds and formaldehyde in schools and occupational environments (Tsitouridou and Papachristou 1991, Siskos *et al.* 2001, Synnefa *et al.* 2003, Valavanidis and Vatista 2006). Therefore, there is a lack of information on the indoor air formaldehyde levels in new houses and apartments in Greece. This study thus aimed at the reduction of that lack by evaluating the indoor concentrations of formaldehyde in thirty brand new apartments.

Materials and Methods

Formaldehyde measurements in the indoor air were made in twenty five brand new apartments in the city of Drama, Greece. The apartments had been very recently occupied (one to three months already) by their residents and were freshly painted. The majority of materials, i.e. cabinets, closets, buffets, were all made of melamine paper or veneer laminated particleboard or fibreboard panels. Most of the insulation materials, carpets and fabrics were also brand new. Indoor air formaldehyde measurements were made in the following areas: (a) living room, (b) bedroom, (c) kitchen cabinets and (d) child room.

A formaldehyde metermodel Triple Plus+ was used in this study with which it was possible to estimate formaldehyde concentrations of indoor air with a relatively limited accuracy. Before each measurement, a calibration of the meter was taking place in the outdoor environment, where the formaldehyde concentration was zero.

For the measurements, the meter was turned on for three minutes and the formaldehyde concentration in each room (in parts per million, ppm) was recorded. In addition, a temperature meter was used to record the air temperature during each measurement. The temperature inside each cabinet was also measured.

Two series of formaldehyde measurements were carried out in this work. The first series of measurements was made in September 2009. Attention was given so that a set of measurements was made during early morning hours prior to any ventilation within the apartments. Following, windows were kept open in each apartment for a ventilation time of 30 minutes and after that a second set of measurements was taken. In the next six months (September 2009 to September 2010), occupants were advised to undertake systematic ventilation every day in the new apartments not only in the morning but also in the late afternoon. In addition, no smoking occurred within the apartments. In September 2010, the second series of formaldehyde measurements was carried out likewise in the selected apartments, as described above.

Results and Discussion

Table 1 summarises the results obtained in September 2009. Measurements revealed that formaldehyde concentrations in all rooms were at high levels (>1.0 ppm). It becomes obvious that these levels exceed by far the limit of 0.1 ppm set in most of the European countries for formaldehyde concentration in residential environments. More specifically, for the measurements made in living rooms, in 14 apartments (56%) formaldehyde concentrations ranged from 1 to 2 ppm. In the other rooms the situation was even worse, since in 23 measurements made in bedroom and kitchen (92%), formaldehyde concentrations ranged from 1 to 2 ppm. Similar results were obtained from the measurements made in child room.

Following the first set of measurements, a 30-minute natural ventilation by opening windows took place in the apartments. A remarkable decrease in the concentrations of formaldehyde was noted. For bedrooms, in only 3 apartments, formaldehyde concentrations were found ranging from 1 to 2 ppm. In the rest (22), formaldehyde concentrations were lower than 1 ppm, while in 13 of them, a zero concentration was measured. Similarly, for living rooms, kitchen rooms and child rooms, in all 25

apartments, formaldehyde concentrations were lower than 1 ppm, 18 of which zero concentration was measured.

The results obtained in September 2010 are shown in Table 2. It has to be mentioned that systematic daily ventilation was carried out in the apartments throughout the period September 2009 to September 2010. Indoor air formaldehyde concentrations in living rooms and bedrooms dropped down dramatically, in most cases at levels below 1 ppm. More specifically, for the measurements made in kitchen rooms, in 6 apartments (24%) formaldehyde concentrations ranged from 1 to 2 ppm. In the other rooms, the situation was even better, since in 21 measurements made in bedrooms (84%), formaldehyde concentrations ranged from 1 to 2 ppm. Similar results were obtained from the measurements made in child rooms and living rooms. Zero formaldehyde concentrations were recorded in the mentioned areas in all of the 25 apartments after a 30-minute natural ventilation. It is apparent that the results obtained in September 2009 show a much cleaner environment in all rooms investigated in these new apartments, as compared with the results of Table 1.

TABLE 1 FORMALDEYDE CONCENTRATIONS IN INDOOR AIR OF 25 NEW APPARTMENTS (AS IN SEPTEMBER 2009)

Area	< 1 ppm	1 – 2 ppm
	Before ventilation (avg. temperature 25.8^{0}C)	
Living room	11	14
Bedroom	2	23
Kitchen room	2	23
Child room	3	22
	After ventilation (avg. temperature 23.9^{0}C)	
Living room	25	0
Bedroom	22	3
Kitchen room	25	0
Child room	25	0

TABLE 2 FORMALDEYDE CONCENTRATIONS IN INDOOR AIR OF 25 NEW APPARTMENTS (AS IN SEPTEMBER 2010)

Area	< 1 ppm	1 – 2 ppm
	Before ventilation (avg. temperature 18.9^{0}C)	
Living room	23	2
Bedroom	21	4
Kitchen room	19	6
Child room	23	2
	After ventilation (avg. temperature 16.3^{0}C)	
Living room	25	0
Bedroom	25	0
Kitchen room	25	0
Child room	25	0

Conclusions

It was found that indoor air formaldehyde concentrations in 25 brand new apartments in Drama, Greece were exceptionally high. In most cases, concentrations exceeded by far the level of 1 ppm. Although this phenomenon is quite common in new houses, the formaldehyde levels observed in this work are extraordinarily high exceeding by far the established non-occupational limits. Moreover, it is concluded that systematic ventilation by opening windows in new apartments on a daily basis can lower formaldehyde concentrations dramatically after a period of six months.

In addition, this work is helpful local customers being informed about the facts that:

- melamine paper or veneer laminated wood-based panels (and subsequently furniture products) of classes E1 and E0 emit much lesser amounts of formaldehyde, and therefore special attention should be given in the course of new apartments furnished,
- natural ventilation of rooms in brand new apartments is necessary, especially in the summer when high temperatures favour formaldehyde emission, and
- smoking inside the new houses should be avoided.

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